THE

CROONIAN LECTURE

ON

MUSCULAR MOTION,

READ AT THE

ROYAL SOCIETY,

NOVEMBER 13TH AND 20TH, 1788.

CORRECTED AND ENLARGED.

LONDON: PRINTED 1790.

BLANE; Sir Gilbert
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TITLE

61/1533
GLASGOW
UNIVERSITY

A

LECTURE

ON

MUSCULAR MOTION.

THIS Lecture was founded by Dr. Croone, who was one of the original Fellows of this Society, having been previouſly a member of thoſe private meetings which laid the foundation of this inſtitution. He was not only a phyſician of learning and eminence, but his character for taſte, as well as for mathematical and natural knowledge, was ſo diſtinguiſhed, that he was elected Profeſſor of Rhetoric in Greſham College*, and was appointed a member of the firſt council of the Royal Society. What prompted him to perpetuate and keep alive an attention to this ſubject was, no doubt, an opinion of its importance and difficulty. There are certain branches of know-

Importance of the ſubject.

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* See Ward's Lives of the Greſham Profeſſors.

ledge which, being conſidered as belonging to particular profeſſions, appear leſs intereſting to men who entertain a taſte for general ſcience; and this has in ſome meaſure been the caſe with inquiries relating to the animal œconomy. But when we conſider the rank which animated beings hold in the ſcale of Nature, and that Muſcular Motion involves ſome of the moſt important circumſtances relating to them, it cannot be denied that this is a ſubject highly intereſting, as a branch of natural knowledge in general, independent of its utility as ſubſervient to medicine. For though ſenſitive beings bear no aſſignable proportion to the great volume of the material world, yet as man belongs to this claſs of exiſtence, and as all other exiſtence would ſeem to be created in vain, unleſs there were beings capable of perception and enjoyment, the inveſtigation of animal nature appears to be of the utmoſt importance, not only as the grounds of a uſeful art, but as an object of philoſophical curioſity.

Extenſive influence of muſcular power in the animal œconomy.

Muſcular motion is juſtly deemed an important and a characteriſtic attribute of animated beings, not only as conferring that loco-motive faculty peculiar to animals, and that power by which they are enabled to exerciſe a command over external objects, but alſo as it conſtitutes that energy by which the motion of the fluids and all the internal functions of the body are carried on. For we are to conſider as muſcles not only thoſe large maſſes of fleſh which compoſe ſo great a proportion of the whole bulk of the body, but likewiſe all the minuter organs ſubſervient to circulation, nutrition, and ſecretion; ſince not only the heart itſelf, but the whole vaſcular ſyſtem and the inteſtines, owe their action to certain powers of irritability and contractility peculiar to muſcular fibres.

In inveſtigating this ſubject, it ſeems moſt natural to begin by comparing the muſcles, and the motion belonging to them, to other modifications of matter and motion that occur in nature.

Properties of a Muſcle in its dead ſtate.

A muſcle, even in ſo far as its ſtructure is an object of our ſenſes in its dead ſtate, has characters which diſtinguiſh it from every other ſubſtance in nature. The moſt ſtriking of theſe, is its regular organization of parallel fibres. The fibrous ſtructure is, indeed, found in other parts of the body, ſuch as the tendons and ligaments, and alſo in vegetables, ſome of which are even poſſeſſed of viſible irritability ; and a ſimilar conformation is manifeſt in ſome minerals, ſuch as the *aſbeſtos* ; but there is a certain degree of tenacity, elaſticity, and moiſture, which, joined to its fibrous organization, diſtinguiſh it from every other form of matter. With regard to the minute ſtructure of muſcles, though ſome have fancied they have ſeen, by the help of glaſſes, the ultimate fibres, and theſe conſiſting either of hollow tubes, or ſtrings of veſicles, or rhomboidal articulations, according to the reſpective theory with which the mind of the obſerver was prepoſſeſſed, it appears, from the beſt microſcopical obſervations, that the fibres are diviſible beyond what the powers of the beſt aſſiſted ſight can trace, and that they are to all appearance uniform.

This regular fibrous ſtructure of muſcles, may be compared to the cryſtalliſation of ſalts, and other regular forms which inanimate bodies aſſume, when paſſing to a ſolid form from a ſtate of ſolution or fuſion. Every ſpecies of matter has a mode of aggregation peculiar to itſelf, when its particles are at liberty to attract each other according to that tendency which has been called their *polarity*. Thoſe who firſt conceived this idea, ſeemed to have proceeded on the ſuppoſition of the ultimate particles of matter being ſolid bodies, infinitely hard, having their different ſides endowed with different powers of attraction and repulſion, ſo as to give various configurations to the parts of matter, when concreting into a ſolid form. There is another and later idea* of polarity, founded on the hypotheſis of the ultimate particles of matter being combinations of attracting and repelling points, which when brought much within the natural limits of theſe powers, produce unequal degrees of attraction and repulſion at equal diſtances from their common centre, thereby defining what may be called the ſhape of the particles, and conſtituting polarity. In whatever manner we conceive this to take place, ſome ſuch circumſtance ſeems univerſal, and perhaps neceſſary to all the varieties of ſolid matter; and there is in ſome inſtances a difference in the appearance and other properties of the ſame ſubſtance, after paſſing from a fluid to a ſolid form, according as its particles have been at liberty to follow more or leſs freely the tendency of their polarity in the act of concretion. This may be illuſtrated by the freezing of water, and the cryſtalliſation of ſalts, which are more or leſs regular or confuſed, according to the circumſtances in which they have taken place. The ſame may be exemplified in metals and other ſubſtances; for it is well known, that the properties of iron and glaſs, in point of coheſion and elaſticity, are very much affected by the quickneſs or ſlowneſs with which they paſs from a ſtate of fuſion to a ſtate of ſolidity. It is probably in ſome circumſtance of this kind that muſcles differ from other ſoft animal matter. We cannot trace by inſpection the manner in which the fluid nutritious matter is *applied* in forming ſolid parts; but as muſcles are compoſed of parts ſo regularly figured and endowed with contractility, it ſeems probable that there is ſome proviſion made by Nature, whereby the particles follow the exact impulſe of their polarity, and conſtitute a more exquiſite ſtructure than in other parts of the body.

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* See Dr. Blagden's Experiments on the cooling of Water below its freezing point. Phil. Tranſ. Vol. LXXVIII. page 143.

So far with regard to the character of a Muſcle, conſidered in its dead ſtate.

Muſcular Motion conſidered in relation to other motions.

The firſt circumſtance that meets the attention in conſidering its living ſtate, is that contractile power or motion, which is properly the ſubject of this Lecture; and in order to inveſtigate its nature, it will be neceſſary to compare it with that which takes place in inanimate bodies, by conſidering the nature of motion in general.

Motion an original and natural property of all matter.

So far as we know, either from actual obſervation, or from analogy, there does not exiſt in nature any ſuch thing as abſolute *reſt:* for when we contemplate the motions of the earth and heavenly bodies, the various complications of the planetary revolutions in their rotation round their own axes, and in the paths of their orbits, in the irregularities ariſing from the diſturbances of their mutual gravitation, and from the preceſſion of the equinoxes, not to mention the influence of the innumerable ſiderial ſyſtems upon each other *, it may be affirmed, on inconteſtible principles, that no particle of matter ever was, or will be, for two inſtants of time, in the ſame place, and that no particle of it ever has returned, or will return, to any one point of abſolute ſpace which it has ever formerly occupied. Whether motion, therefore, can ſtrictly be called an *eſſential* property of matter or not, it is, certainly, by the actual conſtitution of nature, originally and indefeaſibly impreſſed upon it; and as reſt does not exiſt in nature, but may be conſidered, in a vulgar ſenſe, as a fallacy of the ſenſes, and in a philoſophical ſenſe, as an abſtraction of the mind, it follows, that what is called the *vis inertiæ* of matter, is not a reſiſtance to a change from reſt to motion, or from motion to reſt, but a reſiſtance to acceleration or retardation, or to change of direction. If it ſhould be alledged, that any given particle or portion of matter is carried along by virtue of the motion of the planet to which it belongs, it may be anſwered, that the earth or any other planet is nothing more than a congeries of ſuch particles, each of which muſt poſſeſs a ſhare of the ſame energy which animates the whole maſs.

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* See Dr. Herſchel's paper on the conſtruction of the Heavens. Phil. Tranſ. Vol. LXXV. page 231.

Farther proof of the active nature of matter.

The active nature of matter is farther proved by thoſe attractions and repulſions which univerſally take place among its parts, however near or remote; and every inſtance of motion within the cogniſance of our ſenſes, in the bodies around us, is referrible, either in itſelf or its cauſe, to ſome mode of attraction or repulſion. Mechanical impulſe being the moſt familiar cauſe of motion in the ordinary events of life, is apt to be conſidered as the moſt ſimple and original cauſe of it; but it is obvious, upon reflection, that it cannot originate in itſelf, and that all colliſions are produced either by the efficiency of living animals, that is, by muſcular action, or by means of ſome operation of nature, depending on attraction or repulſion. Of the firſt kind, all the mechanical operations of art are examples; and with regard to the others, they may, if carefully inveſtigated, be referred in every inſtance, either immediately or remotely, to the above-mentioned inherent energies of matter. The natural agitation of air or water, for inſtance, may produce motion by impulſe, or may bring two ſolid bodies to impinge upon each other; but it is evident that theſe motions in the atmoſphere

Mechanical impulſe cannot be a primary cauſe of motion.

or the ocean, could not take place without gravitation, which is one of the attractive powers of matter.

Hypotheſis of attraction and repulſion conſtituting the eſſence of matter.

Attraction and repulſion may be conſidered as one principle, inaſmuch as they are both expreſſive of that active ſtate originally inherent in matter, and becauſe any two particles, having affinity with each other, either attract or repel, according to their diſtance, their common temperature, and other circumſtances; and it is ſo univerſal an agent in nature, that ſome modern philoſophers have made it abſorb, as it were, every other power and property of matter. The late Father Boſcovich*, of Milan, about forty years ago, advanced a very bold doctrine to this effect, alledging, with great ſtrength of argument, illuſtrated by geometrical reaſoning, that there does not exiſt in nature any ſuch thing as impenetrable extended particles; and he deduces all the phænomena of the material world from one principle, which ſuppoſes it conſtituted of points having ſeveral ſpheres of attraction and repulſion, which being variouſly arranged and combined, produce the different forms and properties of matter, and its ſeveral powers, ſuch as chemical attraction, coheſion, and gravitation. Whether this hypotheſis is founded in truth or not, it would appear from the reaſonings made uſe of, that all the relative properties of matter may be accounted for, though we abſtract from every other conſideration but attraction and repulſion.

Muſcular motion cannot depend on any mechanical cauſe;

It is evident, therefore, that whatever may be the cauſe of muſcular motion, it is not referrible to mechaniſm, which is itſelf only

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[*] See this doctrine fully explained, in a work entitled, *Theoria nova Philoſophiæ naturalis redacta ad unicam legem, &c. Auctore Rogerio Boſcovich. Venetiis,* 1763.

a ſecondary principle. Some theories have had recourſe to the conveyance of a fluid into the fibres of muſcles, by which they were ſwelled, and thereby ſhortened. One of the moſt plauſible of theſe hypotheſes ſuppoſes this fluid to be the blood; but this is plainly a *petitio principii*; for, in order to give motion to the blood, the very power in queſtion is neceſſary. Other fluids have been ſuppoſed to have this effect, but even the exiſtence of theſe has not been proved. I will not detain this learned audience with a recital of the numerous theories of this kind that have been invented by fanciful and ingenious men, only *one* of which can be true, and the moſt ſolid objections could be urged againſt them all. Other arguments, derived from the nature of irritability and ſenſibility, could, if neceſſary, be brought to prove that Muſcular Motion cannot depend on any mechanical cauſe: but this part of the ſubject was fully treated of by the ingenious Gentleman who delivered the Croonian Lecture laſt year.

But an original law of Nature.

As it has been proved that all matter is in a ſtate of perpetual motion, originally impreſſed upon it by Nature, alſo that attraction and repulſion are eſſential to it, and the ultimate cauſes of all new motions that can ariſe in the univerſe, mechanical action being only a ſecondary cauſe, it ſeems moſt agreeable to the analogy of nature, to refer Muſcular Motion to an original law of animated matter, whereby its particles are endowed with an attractive power for which no cauſe can be aſſigned, any more than for gravitation, coheſion, or chemical affinity. If I underſtand it right, this was the doctrine laid down and illuſtrated laſt year by Doctor Fordyce, and to which I am endeavouring to contribute ſome additional proofs and illuſtrations, from a conviction that it is the only rational and philoſophical light in which this ſubject has hitherto been viewed.

A proof of this from the increaſed power of coheſion.

If the ſhortening of a muſcular fibre depends on this increaſed power of attraction between its particles, the effect of it will be to add to the power of coheſion in the fibre, and if this ſhall be found in fact to be the caſe, it will be a farther proof of the doctrine juſt now advanced. In order to decide this, I made the following experiment upon the flexor muſcle of the thumb of a man, five hours after death, while the parts were yet warm and flexible. All the parts of the joint having been ſeparated, except the tendon, a weight was hung to it, ſo as to act in the natural direction, and was increaſed gradually till the muſcle broke, which happened when twenty-ſix pounds had been appended. I found that a man of the ſame age, and the ſame apparent ſize and ſtrength, with the ſubject of the preceding experiment, could with eaſe lift thirty-eight pounds by the voluntary exertion of the ſame muſcle. It is farther in proof of this fact, that in the caſe of a violent ſtrain from muſcular contraction in the living body, it is the tendon that gives way, whereas we have ſeen, in the experiment juſt now related, that in the dead body, the muſcle is the weaker of the two. It is alſo well known, that in caſes of over-exertion, the muſcular fibres themſelves do not give way, though the ſtrongeſt tendons, ſuch as the *tendo Achillis*, and even bones, ſuch as the knee-pan, are broke by their living force *, which, in ſuch inſtances, muſt be many times greater than the ſtrength of the dead fibres.

Experiment.

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* There is a caſe related in the Philoſophical Tranſactions, by Mr. Amyand, wherein the *os humeri* was broken by an exertion of the muſcles. See Phil. Tranſ. Vol. XLIII. page 252. Every one has obſerved or heard of fractures happening from very ſlight accidents. Theſe occur moſt probably from a jerk of the muſcles concurring with the external violence.

Proof from the increaſed hardneſs.

The ſenſible increaſe of hardneſs in a muſcle, when in a ſtate of contraction, may alſo be conſidered as a proof of an increaſed attraction of its particles to each other at that time.

Whether muſcular contraction produces a change of denſity.

In inveſtigating this ſubject farther, it is of importance to determine, whether or not a muſcle, when in a ſtate of contraction, undergoes any change of denſity. A compariſon of it in this reſpect with dead matter, may throw ſome light on the nature of muſcular action.

Every homogeneous body poſſeſſes a certain degree of denſity, determined by the diſtance of its integrant particles. The moſt common means in nature, by which the denſity of ſuch bodies is altered, are heat and cold ; the one univerſally producing expanſion, the other condenſation. Whether mechanical force has the ſame effects is a point in natural philoſophy not ſo well aſcertained ; for though tenſion and colliſion produce in ſolid elaſtic bodies a change of figure, which they immediately reſume when the force is withdrawn, it has not been enquired, ſo far as I know, whether in ſuch caſes, a change of denſity takes place while the body is in the ſtate of elongation or compreſſion. Two elaſtic balls, in the act of colliſion, undergo a momentary change of figure, ſo that there muſt be an approximation of particles in the direction in which they are flattened ; and in the elongation of an elaſtic chord by tenſion, there muſt be an increaſed diſtance of the particles in one direction, but while theſe changes take place in one dimenſion of the reſpective bodies, they may be compenſated by contrary changes in the other dimenſions ; ſo that the ſeveral bodies may preſerve, upon the whole, the ſame ſolid contents. In order to aſcertain this in the caſe of tenſion, which is the only caſe bearing analogy to Muſcular Motion, I made the following experiment: I took a piece of the elaſtic gum, or *kahoutchouck*, three inches ſquare, and about the eighth of an inch in thickneſs; I procured a piece of ſheet-tin, three inches broad, and ſix inches long, cut into ſharp teeth at each end. The gum was firſt weighed in air, and found to be 380.25 grains. It was then weighed in water, along with the tin, to which it was looſely attached, and the weight of both was then 758,75 grains. The gum was then ſtretched upon the tin, by means of the teeth at each end, to a ſurface of about five inches ſquare, the tin being bent ſo as to leave a free ſpace between it and the gum, in order that when immerſed in the water, no air bubbles might be entangled. In this ſituation, the weight of both in water was found to be 746,75 grains. Here was a difference of twelve grains, which could be owing only to a diminution of ſpecific gravity; and in order to be ſure that there was no fallacy nor inaccuracy in the experiment, the gum was immediately afterwards diſengaged from one end of the tin, ſo as to allow it to ſhrink, and being again weighed in this ſtate in the water, it was found to have recovered exactly its former weight. This, as well as the ſubſequent ſtatical experiments, was performed by means of the exquiſite balance lately invented and conſtructed by Mr. Ramſden, and belonging to Sir Joſeph Banks, who politely allowed me the uſe of it. I was alſo aſſiſted by Mr. Gilpin, clerk of this ſociety, who is extremely accurate and expert in all operations of this kind.

Experiment.

Now, does the ſtate of relaxation and contraction make in like manner a temporary difference in the denſity of muſcles? When the circumſtance of *decurtation* only is conſidered, we ſhould be tempted to think that there muſt be an approximation of the particles of the fibre;

Experiments to determine whether the denſity of a Muſcle is affected by contraction.

fibre ; but there is at the ſame time a lateral ſwelling of the muſcle, which may compenſate for what is loſt in the other dimenſion. This point cannot be decided but by an experimental examination. It might be determined whether a muſcle occupies moſt ſpace when relaxed or when contracted, by finding its ſpecific gravity in each of theſe ſtates by means of the hydroſtatical balance. But this would be found extremely difficult ; for the ſtate of contraction is very tranſitory, and the motion itſelf would produce ſuch a diſturbance, as would render the reſult unſatisfactory. As there is this obſtacle to the experiment on a living muſcle, it occurred to me that it might be performed on the muſcles of a fiſh, which had undergone the operation of *crimping*, as it is called ; for, in conſequence of dividing the muſcles, by cutting them when alive, they undergo a contraction, which continues after death * ; and upon comparing, by the hydroſtatic balance, portions of muſcle which had been crimpt, with thoſe of the oppoſite ſide of the ſame fiſh, which had on purpoſe been ſaved from this operation, it did not appear that there was any difference in the ſpecific gravity. Two trials were made, one with the maſſeter muſcles of a ſkate, the other with the ſides of a large trout.

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* It has been made a queſtion, whether life and its actions may not affect the *abſolute* gravity of bodies ? Though this doubt has not ariſen upon any aſſignable grounds that I know of, unleſs it be that one unknown principle may affect another equally unknown, I thought it might be worth while to determine it by experiment. The firſt trials were with animals of warm blood incloſed in oilſkin, and cloſe tin veſſels, but not being ſatisfied with the accuracy of theſe, from the difficulty of cutting off all communication with the external air, ſo as to prevent moiſture from exhaling, I incloſed live eels in flaſks, and ſealed them hermetically ; and, in this ſituation, their weight when alive being compared with their weight when dead, there did not appear any reaſon to ſuſpect that the mere circumſtance of life made any difference in regard to gravity.

The following experiment was alſo made, in order to decide the comparative denſity of a contracted and relaxed muſcle. I took a glaſs flaſk, into which one half of a living eel was introduced. The mouth was immediately afterwards fuſed by a blow-pipe, and drawn into a tube like the ſtem of a thermometer. The flaſk and tube were then filled with water, in order to ſee whether the motion of the animal would make the fluid riſe or fall. It had neither the one effect nor the other, though there were at times ſtrong convulſions, and if the muſcles had at any one time occupied either more ſpace or leſs than at another, a ſenſible fluctuation would have been produced, eſpecially when the column of fluid was rendered very fine, by the introduction of a ſteel wire to irritate the parts. That part of the eel from the *anus* to the tail was made uſe of for this experiment, as the other diviſion, containing the organs of reſpiration and the air-bladder, might have occaſioned a fallacy, from the expanſion or condenſation of an elaſtic fluid, by accidental changes of temperature, or compreſſion. This was repeated three times, with the ſame reſult. In one of the trials, the abovementioned portion of two eels was introduced, and though they were at times both in convulſions at once, not the leaſt motion of the fluid in the tube could be perceived.

Contraction produces no change of denſity;

I was the more deſirous to be accurate in this and the preceding experiments, as the reſult of them was different from my own prepoſſeſſion at the time, and different, I believe, from the opinion of moſt modern phyſiologiſts. It may ſafely be inferred from them, that the contraction of a muſcle produces no change in its denſity, and that animal life differs from inanimate matter in this reſpect, as well as in moſt of its other properties and laws. One purpoſe in nature for muſcles always preſerving the ſame denſity may be, that as ſome of them act in confined cavities, inconvenience might ariſe from their occupying more ſpace at one time than another. In the extremities of cruſtaceous animals, for inſtance, which are filled with muſcles, a change of denſity would be apt to burſt them. This may alſo be conſidered as a proof of the fact itſelf.

Nor of temperature.

Another circumſtance in which the contractions of muſcles differs from ſimple elaſticity is, that the former, however frequent and violent, does not produce any heat as colliſion and tenſion are known to do. This may admit of ſome cavil with regard to animals of warm blood; for, one of the theories with regard to animal heat is, that it ariſes from the perpetual vibration of muſcular fibres, particularly thoſe of the vaſcular ſyſtem; but this will not hold with reſpect to animals of cold blood, in which the actions of life are equally vigorous.

Recapitulation and compariſon of facts.

The principal phænomena, therefore, of Muſcular Motion, are the ſhortening of the fibres, the lateral ſwell, the increaſe of coheſion and hardneſs, and the unchanged denſity and temperature. It would appear, from the two laſt circumſtances, that the intimate motions of the particles in relation to each other, muſt be different from what take place in the ſeveral inſtances of contraction and expanſion in dead bodies. In the expanſion ariſing from the action of heat, and the contraction from cold, the change of denſity ſhews that in the one caſe, the ultimate particles muſt recede from each other; and in the other caſe, that they muſt approach. The ſame may be ſaid of elaſticity. But as there is no alteration of the denſity

ſity of a muſcle in paſſing from relaxation to contraction, this change cannot conſiſt in the approximation of the integrant parts of the fibres, but muſt depend on ſome other circumſtance in the intimate diſpoſition of the particles. In attempting to conceive in what this conſiſts, the following explanation may be offered:—

A Theory of Muſcular contraction.

It was formerly mentioned that the regular ſtructure of ſolid bodies depended on the polarity and ſhape of their integrant parts. Now all bodies, except ſuch as are ſphærical, muſt have a long and a ſhort axis; and let us imagine the fibres of muſcles to be compoſed of ſphæroidal particles; we may then conceive relaxation to conſiſt in their being diſpoſed with their long axis in the line of the fibres, and contraction to conſiſt in their ſhort axis being diſpoſed more or leſs in that direction. This will not only account for the decurtation, and uniform denſity, but for the lateral ſwell, and alſo for the increaſed hardneſs and coheſion; for though the particles do not approach or recede, as in bodies ſimply elaſtic, yet their power of attraction will be increaſed by their centres being brought nearer, and by being applied* to each other by more oblate ſurfaces. This hypotheſis accords with what has been before proved, concerning the unchangeable denſity; for what is loſt in one dimenſion, is gained in another; and the cauſe for there being no increaſe of temperature, depends probably on the ſame circumſtance by which the denſity is preſerved unaltered.

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[*] By being applied, I do not mean that they are actually in *contact*; for it is evident, from the effect of heat in expanding bodies, and of cold in condenſing them, that there can be no ſuch thing as contact of the ultimate particles of matter, even on the ſuppoſition that theſe conſiſt of impenetrable bodies infinitely hard.

This account of Muſcular Motion does not account for the operation of *ſtimuli*.

WHAT has been hitherto advanced on this ſubject, has tended only to explain that ſtate of a muſcular fibre which renders it ſuſceptible of contraction, and to aſcertain the nature of that change which takes place in paſſing from the ſtate of relaxation to that of contraction. It ſtill remains a queſtion by what efficient power this contraction is excited. We have, indeed, referred the cauſe to attraction; but of attractions ſome are perpetual, ſuch as gravitation, which exerts an equal and unremitting *niſus* upon every particle of matter, which is the ſubject of its action; and there are others fugitive and occaſional, ſuch as electricity and magnetiſm, and we may add muſcular contraction. With regard to the firſt kind, as it is always uniform, it ſeems ſufficient to ſay, that it exiſts as a part of the invariable conſtitution of nature; but with regard to that which is fluctuating, it ſeems incumbent on thoſe who ſearch into the laws of nature, to ſay by what mode of efficiency the attraction is performed, ſo that its action ſhould take place at one time, and not at another. In order to anſwer this queſtion, with regard to Muſcular Motion, we ought to be able to ſpecify by what mode of operation a *ſtimulus* excites contraction. Thoſe theories which account for the contraction of muſcles, by the ſwelling of the fibres, in conſequence of a conveyance of matter, profeſſed to account for the operation of *ſtimuli*; but upon the principles I have adopted in this Lecture, I am obliged to confeſs my entire ignorance on this ſubject. Perhaps it is inſcrutable. Perhaps the ſtate of human knowledge is not ripe for ſuch an inquiry; for we are ſtill in the dark with regard to moſt of thoſe properties of matter which bear any analogy to this, and the knowledge of which might tend to throw light upon it. We know that electric attraction depends on the accumulation of a ſubtle fluid, but we are ignorant of the nature of magnetiſm. With regard to heat, which is univerſally a cauſe of repulſion, and the moſt general, powerful, and active, as well as the moſt uſeful and familiar agent in nature, it is hardly decided as yet whether it is a matter or a quality; and with regard to light, though it is itſelf the medium by which we become acquainted with the moſt remote objects, it is ſo obſcure in its own nature, that it is ſtill a queſtion whether it conſiſts in the tranſmiſſion or vibration of a ſubtle fluid.

As I am unable, therefore, to explain the *operation* of *ſtimuli*, I ſhall content myſelf with endeavouring to *enumerate* them.

Enumeration of Stimuli.

Every natural cauſe exciting the contraction of a muſcular fibre, is called a *ſtimulus*. They may be divided into internal and external. As an example of the former, the circulation of the blood may be mentioned; as this is kept up by an exciting influence of the blood upon the heart and veſſels which contain and impel it. The earlieſt perceivable inſtance of Muſcular motion, is the beating of the heart, as it is ſeen in the firſt rudiments of the embryo in an egg, and called the *punctum ſaliens*. There ſeems to be eſtabliſhed by nature, a certain *habitude* of action between the veſſels and their fluids, whereby the former are duly ſtimulated to propel the latter. This does not depend merely on the acrimony of the fluids; for if a fluid even more mild than the blood, ſuch as milk, be injected into the circulation, it will produce great diſturbance; and if the blood, by being deprived of the influence of reſpirable air, becomes deſtitute of a certain property which it would naturally acquire in the act of reſpiration, it does not prove a *ſtimulus* to the heart.

1. Internal ſtimuli.

The

All the functions of the body are carried on by ſpecific *ſtimuli.*

The irritability of all the containing parts, is in like manner accommodated to the nature of their reſpective contents. The inteſtines are ſo calculated, as to have proper motions excited in them by the aliment, and the ſecretions which are mixed with it; and there are bodies which, though perfectly mild, ſuch as alimentary ſubſtances of difficult digeſtion, yet excite more violent commotions in the ſtomach than other ſubſtances which are very acrimonious. The various effects of poiſons in different parts of the body, may alſo be mentioned as an illuſtration of the peculiar ſuſceptibility of the ſeveral organs of the body. The poiſon of a viper, for inſtance, is perfectly innocent, not only in the receptacles of the animal which produces it, but it may be taken into the ſtomach of any animal without the leaſt bad effect, and only exerts its deleterious power when brought in contact with a wounded part. Some vegetable poiſons, on the contrary, ſuch as that of laurel water*, prove deadly, when taken into the mouth, or applied to any part of the alimentary canal, but are innocent when injected into the veins. The ſame principle might be illuſtrated by the operation of various medicines, ſome of which act upon one ſet of organs, and ſome upon another. But it is meant here more particularly to elucidate the natural internal actions of the body; and it may be remarked, that the receptacles of the ſeveral ſecreted fluids, ſuch as the gall bladder, and bladder of urine, are ſo adapted to their natural contents, by a due meaſure of irritability, as to bear their accumulation to a certain degree, and then to expel them. We have here alſo a proof that irritability is not in proportion to ſenſibility; for both theſe receptacles are extremely ſenſible to pain and irritation, from extraneous acrimony, though ſo moderately ſenſible to the acrimony of their natural contents. This diſpoſition in the ſeveral organs to perform their natural functions, in conſequence of the *ſtimulus* of the reſpective fluids they contain, has aptly enough been called the natural *perception* of theſe organs *.

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* See Experiments on Poiſons, by Abbé Fontana.

It follows from this, that the application of chemical and mechanical *ſtimuli* to irritable parts, is not a mode of experiment likely to be productive of uſeful knowledge, ſince the internal organs are calculated to perform their actions in conſequence of peculiar and ſpecific *ſtimuli*, provided by nature; and this conſideration may ſerve to ſuggeſt the moſt likely means of reſtoring loſt irritability and action to the vital functions, when ſuſpended by ſuffocation, ſtrangulation, or ſubmerſion. The action of the heart depends on the action of the lungs and the inſpiration of atmoſpheric air; and I have found, from repeated experiments on animals, that in ſuch caſes, all other means of reſtoring circulation and life, are of little or no avail, in compariſon of inflating the lungs with atmoſpheric air, and by ſtroking and preſſing the ribs, ſo as to imitate the action of reſpiration. Neither mechanical friction, nor any other external *ſtimulus*, nor ſtimulating clyſters, ſeemed to have any ſenſible effect in recalling life. The only other means, beſides thoſe above mentioned, that ſeem material in attempting to reſtore ſuſpended animation, is a due attention to the external temperature. In the caſe of drowning in cold water, for inſtance, it is of the utmoſt conſequence to reſtore the natural warmth, either by the cautious uſe of artificial heat, or the application of living bodies. In the caſe of thoſe who have been ſuffocated by foul air, it is, on the contrary, adviſeable to expoſe them to cool air.

Application of this in ſuggeſting the means of reſtoring life in caſe of ſtrangulation, &c.

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* This idea is well illuſtrated by Mr. Hunter in his lectures; alſo by Mr. Mudge, in a diſſertation on the *vis vitæ*, ſubjoined to a tract, entitled, "A radical and expeditious cure for a catarrhous cough."

And to pathology.

From what has been before advanced, concerning that habitude or mutual influence of the ſolids and fluids, it would appear that they are ſpecifically appropriated to each other, in order to carry on not only the circulation, but the important functions of digeſtion, abſorption, ſecretion, and excretion; and as the healthy condition of an animal conſiſts in the maintenance of that natural harmony, ſo muſt the ſtate of diſeaſe depend on the derangement of thoſe delicate impreſſions and nice ſenſibilities, or rather *irritabilities*, in which the functions of the ſeveral organs conſiſt; and as the affections of the ſolids and fluids are reciprocal, diſeaſe may depend either on ſome deviation of the former, from their healthy and natural perceptions, or from ſome acrimony or vitiation of the latter, or perhaps more commonly from the concurrence of both, in conſequence of their mutual influence. When the fluids only are morbidly affected, nature alone is poſſeſſed of reſources of cure; for if the containing ſolids retain their natural irritability, they will be ſtimulated to expel what is extraneous or vitiated. A depraved ſtate of the ſolids is therefore likely to prove a more frequent cauſe of morbid derangement; and as they differ from the fluids, by poſſeſſing an inherent activity, it is the object of medicine to incite, reſtrain, or alter their diſeaſed actions, according to the nature of the morbid affection.

Exemplified in the abſorbents.

It is evident, that this doctrine will admit of a much more extenſive application in pathology, than there is time here to follow out; and I ſhall confine myſelf to the illuſtration of it, in the caſe of the abſorbent veſſels. Theſe evidently poſſeſs a power of abſorbing certain ſubſtances, and rejecting others. The lacteals, for inſtance, in a ſtate of health, take up only the nutritious part of the alimentary maſs ; for there is in the fecal part ſubſtances equally ſoluble as the chyle. The inner ſurface of the gall bladder is beſet with abſorbents, which, however, do not abſorb bile in the ordinary ſtate of health, and only concentrate it by taking up the fluid with which it is diluted. But when in conſequence of the obſtruction of the gall ducts, the bladder becomes over diſtended, or when the ſpecific perception of the abſorbents is depraved by diſeaſe, in theſe caſes the bile is abſorbed and thrown into the circulation. Sometimes, ſuch unuſual actions of the abſorbents are excited as a reſource of nature, either to cure diſeaſe, or to carry on growth ; for it has been ſhewn by Mr. Hunter, that not only ſoft and fluid parts, but bone, can be removed by abſorption. At other times, diſeaſe conſiſts in affections of theſe veſſels, either by their action being too much retarded, as in the caſe of dropſy, or where the matter of an ulcer, or in the puſtules of the ſmall pox, is prematurely abſorbed, in conſequence of the depraved action of fever. It is ſufficiently demonſtrable, that the whole ſurface of the ſkin and *bronchiæ* is beſet with inhaling veſſels, which abſorb the fluids diſſolved in the atmoſphere ; and it would be contrary to the analogy of the reſt of the body, to ſuppoſe that theſe are not poſſeſſed of ſome elective power, whereby they prefer or reject ſuch fluids as are preſented to them, according to their ſeveral qualities, and that this power ſhould not be various, according to the ſtate of health or diſeaſe. But, independent of analogy, the variable ſtate of the human body, in reſpect to its ſuſceptibility of contagious diſeaſes, ſeems to be a direct proof of this. It is a well-known fact, that a perſon who has never had the ſmall pox, will at one time be cloſely expoſed to their infection, and yet eſcape the diſeaſe, and at another time will be affected by the ſlighteſt degree of it. If it ſhould be ſaid, that the poiſon is inhaled in the one caſe as well as the other, but that the internal ſtate of the body is in one caſe diſpoſed to be affected, and in the other not, it may be anſwered, that any method by which it can certainly be introduced, as by inoculation, will almoſt infallibly produce this diſeaſe in conſtitutions that have never before undergone it. And this ſeems to afford a ſolution of a much agitated queſtion, On what does the ſuperior ſafety of the inoculated ſmall pox depend? For, in a conſtitution already morbidly diſpoſed, the powers of life will be more apt to give way to any diſturbance that may be excited; and the ſame derangement of nature, which, in this caſe, makes the inhalant veſſels admit the noxious effluvia of diſeaſe, will render the body leſs capable of counteracting it when admitted. In the caſe of inoculation, the poiſon is not taken into the circulation by any natural operation of the body; but being obtruded by art, there is no particular propenſity in the conſtitution to give way to it, unleſs the time of inoculation ſhould accidentally coincide with thoſe moments in which the body is naturally ſuſceptible; and as this muſt ſometimes happen, it is accordingly obſerved, that one caſe in a great number of inoculated ſmall pox, is equally malignant as any caſe of the natural ſort.

The ſuperior ſafety of inoculation accounted for.

Analogy between motion and ſenſation.

The ſpecific irritability of muſcular fibres, in conſequence of the peculiar action of *ſtimuli*, has been called *perception*, as was mentioned before. This term is not to be taken in a ſenſe ſtrictly literal, but as a metaphor, borrowed from ſenſation, and applied to motion. In like manner as the ſenſes are fitted to convey peculiar ideas, in conſequence of their reſpective organs being adapted to their correſponding external impreſſions, ſo are the various organs of motion by nature made ſuſceptible of excitement from peculiar impreſſions, either internal or external. This analogy is the more exact, that the nerves ſeem to be the inſtruments of both; for not only the organs of ſenſation and voluntary motion, but thoſe of involuntary motion, are ſupplied with nerves, and dependant upon them; for if the influence of the nerves leading to the heart or inteſtines is interrupted, by cutting ligature or palſy, the function of theſe parts is thereby deſtroyed. Thus, as there is a peculiar ſenſibility belonging to the ſeveral ſenſes, ſo is there a peculiar irritability belonging to the ſeveral organs of motion. The intention of Nature, therefore, in diſtributing nerves to every muſcular organ, was probably in order to conſtitute thoſe peculiar perceptions on which the various vital and natural functions depend. But I give this only as a conjecture; and though the nervous influence may thus *modify* irritability, there is reaſon to think that it does not *beſtow* it.

Whether vitality is dependant on the nervous ſyſtem

This leads us to conſider how far vitality is dependant on the nerves. It has been the opinion of ſome phyſiologiſts, who have been ſuppoſed to entertain very rational ideas of the animal œconomy, that all muſcular irritability depended on a ſentient principle [*]; and ſome have even maintained, that there is an intelligent principle [†] reſiding in animal bodies, in order to guide their functions and operations. From the preceding facts and reaſoning, and from its being well atteſted that there have been ſeveral inſtances of the production of fœtuſes, without the brain [‡], there ſeems no occaſion to have recourſe to ſo violent a hypotheſis. This, however, is not the queſtion here intended to be diſcuſſed ; but it is meant to enquire, whether or not there is a foundation in nature for an opinion broached by Mr. Hunter; that there is a living principle, diſtinct from the nervous ſyſtem, and independent of ſenſation and conſciouſneſs. The principal fact in ſupport of this opinion, is the exiſtence of animals without brain and nerves. That there are ſuch, was, I believe, firſt obſerved by Haller *, and has been confirmed by Mr. Hunter ; who maintains farther, that the ſtomach is a centre, or ſeat of life, more eſſential to it than the brain. That the ſtomach ſhould be an organ of ſo much conſequence, ſeems natural enough, from the importance of its function, which is that of aſſimilation ; and life can be more immediately and completely extinguiſhed by an injury to it, ſuch as a blow, than by the ſame violence to any other part of the body. It is alſo well known, that the muſcular fibres of animals, endowed with a nervous ſyſtem, will retain their irritability for ſome time after their ſeparation from the brain and nerves. It is evident, likewiſe, from the *phænomena* of vegetation, that irritability may exiſt in nature, without ſenſation, conſciouſneſs, or any ſuſpicion of the exiſtence of a nervous ſyſtem. The facts I allude to, are not only the perceptible motions of the ſenſitive plant, but more particularly thoſe motions which muſt neceſſarily take place in all plants, in carrying on their growth ; for there is no accounting for the accretion of ſolid parts, in conſequence of the conveyance of nutrition by the propulſion of the ſap, but by admitting ſome power, acting by laws different from thoſe of dead matter. In favour of this opinion, it is farther obſervable, that thoſe animals which are deſtitute of brain and nerves, are of the claſs *vermes*, the moſt ſimple in nature, having only one function, to wit, that of *aſſimilation*, and therefore not requiring that variety of action, and thoſe peculiar perceptions which are neceſſary to more complex animals. Laſtly, the ſtate of an egg before incubation, and the condition of thoſe animals which become torpid from cold, and afterwards revive, afford facts which favour this opinion; as they ſhew that there is a certain principle of ſelf-preſervation, independent not only of the operation of the nervous ſyſtem, but even of the circulation; for, in this quieſcent ſtate, theſe portions of animal matter are preſerved for a great length of time from that corruption to which they would otherwiſe be liable, and their fluids are prevented from freezing in a degree of cold, which would congeal them, were they deſtitute of every principle of life.

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[*] See Whytt on the vital and involuntary motions.

[†] *Vide Opera Stahlii & Prelectio de anima medica, Auct. Doct.* Nicholls.

[‡] See Phil. Tranſ. Vol. XIX. and XXI.

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* *Vide Primas Lineas Phyſiologiæ,* ccccii.

The mutual dependance of ſimple life and nervous influence.

But though ſimple life may be conſidered as diſtinct from the nervous ſyſtem, which is only an acceſſary appendage to it, yet in thoſe animals in which they are conjoined, the purpoſes of nature render them dependant on each other. The functions of the brain, for inſtance, cannot go on without the action of the heart; for whenever the circulation of the blood is interrupted, conſciouſneſs and ſenſation are deſtroyed, as is evident in the caſe of a ſwoon, and in the effects of ſtrangulation. On the other hand, as has been before obſerved, the action of the heart has a dependance on the influence of the nerves, as connected with the brain. There are alſo inconteſtible proofs of the extreme veſſels being affected by the influence of the brain; for we know that a thought in the mind will produce partial determinations of the circulating fluids, as in the caſe of bluſhing, and the fullneſs of the veſſels in the organs of generation, in conſequence of certain paſſions. It does not, however, follow, from all this, that irritability depends on the nerves; the influence of which may be conſidered as modifying general irritability, in the manner already mentioned; or it may be conſidered rather as a *ſtimulus* to the muſcular fibres, than as endowing them with irritability, as in the inſtances laſt adduced: and though the organs eſſential to life, ſuch as the heart, cannot exert the action neceſſary to life, without the influence of the nerves, yet the veſſels of the extremities can exert their uſual action independent of it; for there are caſes in which the natural heat and circulation continue in the limbs, after a total deprivation both of voluntary motion and ſenſation *.

Eſſential properties of ſimple life.

It may here be obſerved, that beſide muſcular irritability, the principal, if not the only, powers of ſimple life, are the aſſimilation of aliment, and that power in the living body, by which it preſerves itſelf from putrefaction; and it is ſtrongly in proof of vitality being independent of nervous power, that when the trunk of a nerve is cut through, the limb to which it leads, though deprived of all ſenſation and voluntary motion, not only continues free from ſpontaneous putrefaction, but the warmth and circulation continue, even though the nerve ſhould not be regenerated *. The only viſible change produced in a limb by this operation, is, that after ſome time it begins to waſte.

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* This fact is aſcertained, both by the experiment of cutting the crural nerve of a living animal, and by the circumſtances attending certain diſeaſes. I lately met with two caſes of palſy, in which there was a total loſs both of ſenſation and voluntary motion in the lower extremities, and yet the natural warmth and circulation remained. In one of theſe caſes, excoriations were produced on the feet by ſinapiſms; and in the other, bliſters roſe on the knees, but without exciting any ſenſation, and the parts healed as in a healthy perſon. The firſt, was that of a gentleman advanced in life, in whom this affection came on after the gout in the ſtomach, and he died in conſequence of the palſy extending to the bladder and other *viſcera*. The other was that of a young woman in St. Thomas's Hoſpital, who had been ſubject to violent hyſterical convulſions. After a tedious illneſs, ſhe entirely recovered the uſe and feeling of her limbs.

The influence of the nervous ſyſtem unfriendly to ſimple life.

But there are circumſtances that would ſeem to prove, that the nervous ſyſtem is not only a mere appendage to life, but that it tends to impede its operation, and ſhorten its exiſtence. Simple life will not only ſurvive ſenſation, but will ſurvive it longer, if the animal is killed, by deſtroying the nervous ſyſtem, than if it had been deſtroyed by hæmorrhage, ſuffocation, or other violence. It is a curious and well aſcertained fact, that if a fiſh, immediately upon being taken out of the water, is ſtunned by a violent blow on the head, or by having the head cruſhed, the irritability and ſweetneſs of the muſcles will be preſerved much longer, than if it had been allowed to die with the organs of ſenſe entire. This is ſo well known to fiſhermen, that they put it in practice, in order to make them longer ſuſceptible of the operation called *crimping*. A ſalmon is one of the fiſh leaſt tenacious of life, inſomuch, that it will loſe all ſigns of life in leſs than half an hour after it is taken out of the water, if ſuffered to die without any farther injury; but if, immediately after being caught, it receives a violent blow on the head, the muſcles will ſhew viſible irritability for more than twelve hours afterwards.

This illuſtrated by obſervations on fiſh,

On quadrupeds,

There is a circumſtance obſerved with regard to animals of warm blood, which ſeems to depend on the ſame principle. An exceſſive exertion of voluntary motion, immediately before death, prevents the muſcles from becoming rigid when cold, and renders them more prone to putrefaction. Thus, if an ox is killed immediately after being overdrove, the carcaſe will not become ſtiff when it grows cold, nor is it capable of being preſerved by means of ſalt.

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* It appears, from ſome experiments of Mr. Cruikſhank, that there is a proceſs in nature, whereby nerves can be regenerated after being cut through.

And diſeaſes of the human ſpecies.

In illuſtration of the ſame principle, it may be remarked, that there is a ſymptom in certain diſeaſes of the human ſpecies, ſhewing that digeſtion, which is one of the principal functions of ſimple life, will ſometimes go on better, in conſequence of leſions of the brain; for in thoſe diſorders in which the exerciſe of the ſenſes is in a great meaſure deſtroyed, or ſuſpended, as in the hydrocephalus and apoplectic palſy, it happens not uncommonly that the appetite and digeſtion are better than in health.

Every exerciſe of the brain produces fatigue.

From theſe facts we may infer, with Mr. Hunter, that the exerciſe of ſenſation is inimical to life, and that a ſort of fatigue is induced by this, as well as by voluntary motion: ſo that all that intercourſe carried on through the nerves, whether *towards* the brain, in the caſe of ſenſation, or *from* the brain, in acts of volition, tends to wea rout the animal powers *. And as intenſe and long-continued thought, though not terminating in any outward action, tends alſo to produce an inability for farther exertions, it would appear that the brain, or ſenſorium, is more particularly the organ which is ſubject to that ſpecies of ſufferance called fatigue. From theſe facts, we perceive the neceſſity of ſleep, which conſiſts in a

Hence the neceſſity of ſleep,

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* There are ſome ingenious remarks on the analogy of ſenſation and motion, in a paper on the ocular *ſpectra* of light and colours, by Dr. Robert Waring Darwin, Phil. Tranſ. Vol. LXXVI. This diſſertation abounds with refined and well-deduced obſervations on the ſubject he treats of.

temporary ſuſpenſion of ſenſation, volition, and thought, and is a reſource of nature, whereby the powers of life recover themſelves after ſatiety and fatigue, which are provided as guards to warn us when nature is in danger of being ſtrained, either by repletion or over exertion; and it is evident that ſuch barriers were abſolutely neceſſary, in order to ſet bounds to operations which are only occaſionally requiſite, and which would otherwiſe depend on the caprices of the will. The exerciſe of ſenſation and voluntary motion, in a moderate degree, is conformable to the intention of nature, and therefore ſalutary; and it is only when they are exceſſive, that they tend to wear out the powers of life, and more eſpecially if theſe are not duly recruited by ſleep. Immoderate labour, therefore, and watching, alſo ſpaſms and convulſions of every kind, are unfriendly to health and long life: in like manner, ſenſations, when too frequent or intenſe, eſpecially thoſe which conſiſt in the gratification of the ſenſes, tend to wear out the animal powers; and hence we perceive why a life of ſenſuality is productive of certain diſeaſes, independent either of the repletion or evacuation which attend them. The gout, but more certainly the palſy, ſeems to proceed merely from the indulgence of the ſenſes; for the latter commonly enough occurs in the moſt ſpare and emaciated conſtitutions, and in thoſe who have been accuſtomed to exhauſting pleaſures, as well as thoſe of a full habit, who have indulged in the exceſſes of the table. A turgeſcence of the veſſels in the brain will certainly be more apt to produce that rupture of them in which apoplectic palſy conſiſts, when theſe veſſels have been relaxed, as we conceive them to be, by frequent and intenſe ſenſations. But in thoſe who are the reverſe of being plethoric, and who fall victims to this diſeaſe, in conſequence of too free indulgence in venereal pleaſures, in the decline of life,

And the bad effect of immoderate labour and ſenſuality.

(as every one who has much obſervation of the world, or experience in phyſic, knows to be a frequent caſe) it muſt ariſe from a preternatural weakneſs in the brain, induced by the mere circumſtance of ſenſation. This accounts for what has been reckoned a difficulty in reaſoning on the cauſe of apoplexy and palſy, to wit, that the ſame effect ſhould be produced by thoſe gratifications which produce repletion, as by thoſe which produce evacuation.

And the good effects of removing irritation in certain diſeaſes.

It follows, from the ſame principle, that when life is threatened by certain diſeaſes, of which the chief ſymptom is irritation, any means by which ſenſation, whether natural or morbid, and muſcular motion, whether voluntary or involuntary, convulſive or ſpaſmodic, can be ſoothed or ſuſpended, will prove ſalutary, by allowing the powers of life to rally, as it were, and recover themſelves. In this conſiſts the operation of narcotic medicines, ſuch as opium, which, in complaints both of a general and local nature, proves uſeful not merely as a palliative, by the removal of temporary pain or ſpaſm, or by procuring ſleep, but as a principal inſtrument of recovery, by allowing the powers of life to exert their natural action, in conſequence of the removal of irritation *.

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* As an example of the general affections of the conſtitution in which opium is a uſeful remedy, we may mention thoſe low fevers in which the principal ſymptoms are tremors, *pervigilum*, and low *delirium*. And as an inſtance of local affections, in which it has been found highly ſerviceable, we may mention ill-conditioned ulcers of all kinds, but particularly thoſe which occur in the venereal diſeaſe. One of the principal difficulties in the cure of this diſeaſe, is that irritability of conſtitution whereby ulcers are ſo exaſperated, by the uſe of mercury, as not to bear a ſufficient quantity of it to produce a cure. This is obviated by a free uſe of opium, which ſeems more efficacious in ſuch caſes, than even Peruvian bark, or any other remedy; and this is one of the principal modern improvements inthe treatment of this diſeaſe.

It is but juſt to own, that this is an idea which was firſt ſuggeſted to me by a learned and eminent phyſician* of this place, when in conſultation with him a few years ago.

Comparative effects of opium upon ſenſitive and ſimple life.

It would be curious, as well as uſeful, to diſtinguiſh the operation of medicines, as they affect ſimple or ſenſitive life. I attempted a compariſon of this kind with opium, which, though it chiefly affects ſenſation, has alſo a powerful effect on ſimple life, as I found by trying its effects upon leeches, which are a ſpecies of animals without brain or nerves. In order to diſcern the power of this drug, as affecting the different principles of animals poſſeſſing both ſorts of life, I took a ſolution of it in water, into one portion of which I put ſome ſound living eels, and into another ſome eels, alſo alive, but having their heads bruiſed, chuſing the former, as nearly as I could, of the ſame vigor with the latter, before their heads were bruiſed. It was found, in a number of trials, that the ſound eels generally died ſooner than the others. The opium had a double effect on the former, as it acted both upon the ſenſes and upon the principle of ſimple life, and the effect upon the ſenſes was more than equivalent to the external injury of the latter, upon which the opium acted only upon one principle, the ſenſes being locked up by the deſtruction of their organs. In order to make this operation ſucceed, the ſolution ſhould be of a certain degree of ſtrength, ſo as to act as a poiſon. There ſhould be at leaſt half a grain of opium to an ounce of water. When the trial was made with a ſolution of half this ſtrength, the ſound eels lived much longer; for the time was then protracted to that period in which the wounded eels would have died merely of their injury. It may be mentioned, that thoſe which had their heads bruiſed, and were put into a ſolution of opium, died conſiderably ſooner than thoſe which had ſuffered the ſame injury, and were put into plain water for a ſtandard.

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* Dr. Warren.

Stimuli connected with conſciouſneſs.

Having conſidered the various qualities of the fluids exciting the correſponding irritability of the reſpective veſſels, as a leading principle in carrying on ſome of the moſt important functions of the body, and ſerving to account for many of the vital and involuntary motions, the only other internal *ſtimuli* that remain to be enumerated, are thoſe connected with conſciouſneſs. The great maſſes of muſcle in the trunk and extremities of the body, are the inſtruments of the mind in acting upon external bodies; and we may, therefore, reckon in the liſt of *ſtimuli*, the nervous power by which the will and the paſſions excite external motions. This is a function ſufficiently important for the nerves, without admitting them as the principle upon which irritability depends. This queſtion has been already diſcuſſed; but it may be farther obſerved, that the nervous power, being a ſtimulus acting upon an irritable principle in the muſcular fibres, affords a preſumption that they are different from each other; for, the matter being conſidered abſtractedly, where any effect is the reſult of the concurrence of two bodies, as, for inſtance, in the combinations of chemiſtry, theſe two bodies muſt be different, in order to produce any given effect. It is otherwiſe, indeed, when the effect depends on mere *communication*, as in the caſe of mechanical impulſe, where the ſame motion that is loſt by one body is acquired by another. But it will not be ſaid, that there is any ſimilarity between what takes place in a nerve, and what takes place in a muſcular fibre in the act of voluntary contraction.

I have already acknowledged my ignorance of the manner in which *ſtimuli* in general operate, and that this muſt be admitted as an ultimate fact in nature. But the operation of the will through the nerves, ſeems involved in double obſcurity; for as it depends on the nature of thought, it cannot be made a ſubject of experimental inveſtigation. For this reaſon I ſhall decline the inquiry, as not being adapted to the ends of this Society; and it ſeems impoſſible for human ſagacity to penetrate the connection of matter with ſenſation and volition, except by inferences more or leſs hypothetical. The properties of different bodies, in relation to each other, appear to be the only proper ſubjects of experimental reaſoning; for, in their relation to the mind, they are only the effects, perhaps the remote effects, of their intimate nature upon the ſenſes; ſo that we may venture to affirm that human reaſon can no more fathom the connection of thought with the correſponding changes in the corporeal organs, than the eye can ſee itſelf.

Effects of the paſſions on muſcular fibres

Thoſe affections of the muſcular fibres, which depend on the *paſſions*, though diſtinct from thoſe excited by the will, may yet be enumerated here among thoſe which flow from conſciouſneſs; for there are emotions of the mind that have viſible and powerful effects on the heart and vaſcular ſyſtem, which are organs entirely out of reach of the will. Not to mention the well-known effects of grief, fear, and joy, which affect the whole circulation, there are certain paſſions and ſentiments which produce partial and local effects. Theſe are eſtabliſhed by Nature, either to anſwer ſome important natural purpoſe, as in the caſe of the congeſtion of the fluids in the parts of generation, in conſequence of the venereal appetite, or to ſerve as natural expreſſions, as in the caſe of bluſhing and weeping. One of the moſt ſtriking effects of the paſſions upon muſcular action, is the influence they have upon the ſtrength or mechanical force of the voluntary muſcles. Fear produces debility, almoſt amounting to palſy. Courage and ardor of mind, on the contrary, adds to the natural ſtrength. When the mind is agitated by ſome intereſting object, and calls upon the body for ſome extraordinary exertion to effect its end, the muſcles are thereby enabled, as it were by magic, to perform acts of ſtrength, of which they would be entirely incapable in cold blood. In circumſtances of danger, for inſtance, where life or honour are at ſtake, exertions are made in overcoming mechanical reſiſtance, which ſeem incredible, and would be impoſſible, were not the mind in a ſort of phrenzy, and it is truly admirable in the œconomy of nature, that an idea in the mind ſhould thus in a moment augment the powers of motion, and inſpire additional reſources of ſtrength, adequate to the occaſional calls of life *. The great increaſe of ſtrength in maniacs, is alſo referrible to the paſſions of the mind. Theſe conſiderations would almoſt lead us to doubt whether or not the accounts we have of the great feats of ſtrength aſcribed to individuals in the heroic ages, are fabulous or not. It is alſo worthy of remark, that in

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* This extraordinary degree of ſtrength, infuſed into the muſcles by ardent paſſions and affections, has been conſidered, by unenlightened minds and heated imaginations, as a *ſupernatural* influence; and the ſtriking effects deſcribed above, may form ſome excuſe for ſuperſtition in attributing them to the ſecret agency of ſome propitious and irreſiſtible power. The etymology of *enthuſiaſm*, a word expreſſive of theſe uncommon exertions, ſhews that there was originally ſuppoſed to be, on certain occaſions, ſome divine influence actuating the human frame. The conſciouſneſs of this increaſed vigor of mind and body, exalted by the belief of its divine ſource, will ſerve to account for thoſe peculiar and aſtoniſhing efforts of enthuſiaſm, which are met with in the hiſtory of mankind.

great and laſting exertions of ſtrength, to which men are impelled by active and generous affections, fatigue is not induced in the ſame proportion, by many degrees, as by the ſame quantity of muſcular action in the cool and deliberate actions of common life*.

2. External *Stimuli.*

The other claſs of *ſtimuli* to be enumerated, are the external. Theſe conſiſt in impreſſions made by outward bodies. They are either immediate, as in the caſe of thoſe motions which are excited by mechanical means, or by acrimony, directly and artificially applied to a muſcular fibre; or they are remote, as in the various inſtances of ſympathy, and in the caſe of thoſe inſtincts which nature has conſtituted for the purpoſe of ſelf-preſervation in brutes, and in the early part of human life. I ſhall here confine myſelf to a few remarks on inſtinct, as the other branches of this ſubject have been fully and ably handled by thoſe who have gone before me in this Lecture.

Analogy between internal and external *ſtimuli.*

There is a connection eſtabliſhed between the impreſſion of certain external bodies and the action of certain muſcles, analogous to what has already been noticed with regard to the internal motions excited in veſſels by the peculiar *ſtimulus* of their fluids, Nature having inſtituted certain habitudes between outward *ſtimuli* and the moving powers whereby natural propenſities are conſtituted, equally neceſſary to the ſupport of life as the internal functions. Thus, in a new-born animal, the firſt contact of the external air excites the act of reſpiration, and the contact of the nipple excites the act of ſucking; both of which actions are abſolutely neceſſary to the maintenance of life, and require the nice co-operation of a great number of muſcles, prior to all experience. Actions of this kind are called inſtinctive, and differ from voluntary motions in this reſpect, that the latter are the reſult of memory and experience, whereas the former are the immediate effect of external impreſſions, in conſequence of an eſtabliſhed law of nature, and independent of conſciouſneſs. The actions of inſtinct and thoſe of volition, nevertheleſs, run imperceptibly into each other, ſo that what was at firſt inſtinctive, may afterwards come to be a matter of deliberate choice. The ſame muſcles are the inſtruments of both, and they differ from the muſcles obeying the internal *ſtimuli*, ſuch as the heart, in this reſpect, that they are liable to fatigue, and thereby concur with the exerciſe of ſenſation and of thought, in rendering ſleep neceſſary. There are no muſcles, except thoſe of reſpiration, of which the conſtant action is neceſſary to life, and which are void of conſciouſneſs in their ordinary exerciſe, but which are yet in ſome meaſure under the control of the will. The principal end anſwered by this power of the will over the muſcles of reſpiration in man, is to form and regulate the voice.

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* See Obſervations on the Diſeaſes of Seamen. Book II. chap. III.

Inſtinct.

Certain inſtinctive actions, independent of ſenſation and conſciouſneſs.

But though inſtinctive motions are in ſome caſes convertible into thoſe which are voluntary, we ſhould be ſo far from confounding them, that the former are even compatible with the want of conſciouſneſs and ſenſation; for thoſe animals which are deſtitute of brain and nerves, are capable of actions evidently of the inſtinctive kind. A leech, for inſtance, being brought into contact with a living animal, is impelled, by an inſtinct of its nature, to faſten upon it, and ſuck its blood. There is ſomething very ſimilar to this even in vegetables, as in the caſe of tendrils and creeping plants being ſtimulated, by the contact of other bodies, to cling round them in a particular direction. There are facts, which ſhew that inſtinctive actions, even in animals endowed with brain and nerves, do not depend on ſenſation. I took a live kitten, a few days old, and divided the ſpinal marrow, by cutting it acroſs at the neck. The hind paws being then irritated by pricking them, and by touching them with a hot wire, the muſcles belonging to the poſterior extremities were thrown into contraction, ſo as to produce the motion of ſhrinking from the injury. The ſame effects were obſerved in another kitten, after the head was entirely ſeparated from the body*. The like takes place with regard to inſects; for, after the head of a bee is ſeparated from the body, the hinder part will ſting, upon the application of ſuch a *ſtimulus* as would excite the ſame action in the animal in a perfect ſtate. Theſe facts ſhew clearly that inſtinctive motions may be exerted, without the intervention of the *ſenſorium commune*, and therefore without ſenſation or conſciouſneſs.

In what I have farther to ſay on this ſubject, I ſhall confine myſelf to the conſideration of two of the moſt curious and important inſtincts, HABIT and IMITATION.

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* In repeating this experiment, I found that when the ſpinal marrow was cut through, between the *lumbar vertebræ* and *os ſacrum*, the poſterior extremities loſt their irritability, but the tail retained it. It might, therefore, be ſaid, that the ſpinal marrow ſerved as a ſenſorium; but it may be anſwered, that when the head is cut off, its irritability remains, as appears by the motion of the ears, when pricked or touched with a hot wire; and as the extremities are alſo irritable, it will not be ſaid that conſciouſneſs and ſenſation exiſt in two ſeparated portions of the body.

Habit, as applied to muſcular motion.

It is the nature of a voluntary muſcle to perform any motion with greater eaſe, the more frequently it is repeated, and to act moſt readily with thoſe muſcles, or in company with thoſe ſenſations with which it has been uſed to combine its action, either at once or in ſucceſſion. This is the foundation of habit, and though it is in common to man with other animals, it is the principle by which all his practical attainments acquire facility and perfection. It has been mentioned that ſome actions, originally inſtinctive, may afterwards be performed as acts of pure volition; ſo inverſely, all actions, which are the reſult of reaſon and reflection, may be brought by habit to reſemble inſtinctive actions, and thereby to be performed with greater expedition and effect.

Habit, as applied to ſenſation.

The term Habit has alſo been applied to ſenſation; for, as motions are more readily excited by frequent ſucceſſion, ſo one perception excites the idea of another, in conſequence of repeated connection. In this ſenſe, it ought more properly to be called the aſſociation of ideas, a principle upon which Dr. Hartley has built a theory * of the human mind, perhaps the moſt juſt and conſiſtent of any that has ever been framed. It is habit, taken in this ſenſe alſo, which Mr. Hume † conceives to be the foundation of all our experimental reaſoning, inaſmuch as it conſtitutes the only original notices by which we acquire any intimation of the connection of cauſe and effect. But though this doctrine is ably and profoundly illuſtrated by that philoſopher, it may be remarked, independently of other objections, that though habit may *give no-*

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* This work has been re-publiſhed, with a preface, by Dr. Prieſtley.

† See Eſſays and Treatiſes on various ſubjects, Vol. III. by David Hume, Eſq.

tice of this connection, it cannot *conſtitute* it; for animals, whether rational or irrational, would be made ſuſceptible of habit in vain, unleſs the conſtitution of external nature had been made to correſpond with it; juſt as the eye would have been made in vain, had there not exiſted ſuch a body as light. Now, in what does this correſpondence conſiſt? It conſiſts in that principle whereby nature acts by invariable laws; for it is evident, that if the laws of nature were variable, thoſe recurrences of perceptions in which habit conſiſts, and on which all experience is built, could not take place; and this ſort of contingency would alſo deſtroy all thoſe principles by which prudence and ſkill operate upon external objects, for the purpoſes either of common life or of ſcience. The faculty, therefore, by which animals are ſuſceptible of that ſort of habit which conſiſts in the aſſociation of ideas, may be termed the organ whereby animals perceive the uniform ſucceſſion of cauſe and effect, eſtabliſhed by the invariable courſe of nature. It was neceſſary that this ſhould be an inſtinct, for the ſake of ſelf-preſervation, not only to mere animals, but to the human ſpecies in infancy. If the noxious effects of fire, and the various modes of mechanical violence, ſuch as falls and blows, were only to be learnt by a proceſs of reaſoning, all animals would periſh before they could attain to maturity. The great difference of man and mere animals in this reſpect, ſeems to be, that the latter only perceive theſe aſſociations, when the objects themſelves are preſent to their ſenſes, whereas the former, by being endowed with memory, can reflect upon them, and render them ſubſervient to experience: for, with regard to external bodies, what is reaſon, but the remembrance of objects as they affect each other, and the application of this knowledge to the practice of life, in adjuſting means to ends? The principal difference of one man from another, in point of underſtanding, conſiſts in the readineſs with which the mind forms theſe combinations, and the ſtrength with which it can guard againſt ſuch as are accidental and fanciful, and diſcriminate theſe from ſuch as have an archetype in the nature of things; and that mind, of which the conceptions correſpond beſt with the real aſſociations of nature, is poſſeſſed of correct judgement and juſt obſervation, the moſt valuable of all mental attainments.

It would lead to diſquiſitions too long and too intricate, and, in ſome meaſure, foreign to this place, to enlarge farther on the various effects of the combination * and ſucceſſion † of ideas which connect animal with intellectual nature. I ſhall only remark, that thoſe internal faculties upon which habit and aſſociation depend, carry a reference to external nature, exactly analogous to the mutual relation formerly mentioned as ſubſiſting between *ſtimuli*, whether internal or external, and the moving powers correſponding to them, and between the organs of ſenſe, and the impreſſions of external bodies which are naturally adapted to them. Muſcular motion and ſenſation have relation to the ſingle properties of matter, as they affect particular fibres and organs, but habit and aſſociation are co-relative to that ſtated connection of cauſe and effect, eſtabliſhed by the general laws of nature. We can thus trace a correſpondence between the motions, ſenſations, and faculties of animals, on one hand, and the properties of matter on the other hand, from the loweſt limits of animal and even vegetable nature,

Correſpondence between the properties and laws of external nature and the faculties of animals.

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* See Theory of the Moods of Verbs, by Dr. Gregory. Phil. Tranſ. Edin. 1790.

† See a Treatiſe on Time, by Dr. Watſon, jun. F. R. S. Lond. 1785.

into the boundaries of intelligence. The ſame accordance with the laws of nature is obſervable in the ſtructure of animals, as in their motions and functions, as may be examplified by that reference to the powers of gravitation which is evident in the conformation of the limbs and the poſition of the viſcera, as adapted to the natural motions and poſture of the body.

It would appear, therefore, that there is a co-ordinance or *pre-eſtabliſhed harmony*, as it were, between the faculties of animals and the laws of external matter, which is the foundation of all the inſtinctive habits of animals, as well as the rational conduct of man; and it is impoſſible ſufficiently to admire that ſublime contrivance by which the frame of animated beings is thus in all points adapted to the conſtitution of inanimate nature.

Habit as applied to thoſe diſeaſes which affect but once in life.

There ſtill remains to be mentioned another circumſtance in the animal œconomy, which has been referred to the law of habit. It is the nature of thoſe morbid poiſons called ſpecific contagions, ſuch as the infectious matter of the ſmall-pox, not to produce their peculiar effect more than once in life; and this has been imputed to habit, from the ſimilarity of it to what happens with reſpect to external impreſſions, the frequency and long continuance of which tend to produce the want of conſciouſneſs and ſenſibility. Upon whatever principle this property of the animal œconomy depends, it is an undoubted fact that theſe morbid poiſons, after exciting a certain degree of diſturbance, and a certain ſeries of diſeaſed actions, no longer make any impreſſion on the powers of life, otherwiſe there could be no ſuch thing as recovery; for at the time in which a perſon begins to recover from the ſmall-pox, the poiſon, actually preſent in the circulating ſyſtem, is multiplied infinitely beyond what it was when it excited the diſeaſe. The conſtitution has therefore, at that time, with reſpect to this acrimony, acquired an inſenſibility, or rather want of irritability, and this it preſerves ever afterwards. This holds only with regard to thoſe morbid poiſons which excite febrile affections, and ſeems to be a neceſſary proviſion of nature to guard againſt ſuch noxious principles as are generated within the body itſelf.

IMITATION.

The other inſtinct that remains to be conſidered, is Imitation. This is an action of which ſome brutes of no great ſagacity are capable, and yet it is the foundation of ſome of the moſt important attainments of rational beings, particularly ſpeech, which could not otherwiſe be acquired, and without which the powers of reaſon would be extremely limited*. In the early part of human life, imitation ſeems equally independent of reaſon and reflection, as in mere animals. It takes place not only without the operation of the will, but in oppoſition to it; for yawning is an involuntary ſpaſm of the muſcles of the jaw, which is frequently excited by a ſight of the ſame action in others; and there is a caſe recorded in the Philoſophical Tranſactions, by Dr. Garden †, of a man who, in his adult ſtate, and poſſeſſed of reaſon, imitated involuntarily and irreſiſtibly whatever geſtures he ſaw in others. We are to account, on the ſame principle, for that general ſimilarity of external manner, and of accent obſervable in particular ſocieties and nations, and which all men inſenſibly acquire in a greater or leſs degree.

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* See ſome ingenious obſervations on this ſubject in Dr. Campbell's Philoſophy of Rhetoric, Book II. chap. vii.

Speech ſeems to be to thought what writing is to ſpeech, or rather what arithmetical or algebraical computation is to common language, whether ſpoken or written; for without ſpeech the operationſ of the mind, particularly that of abſtraction, would be extremely limited, nor could there be any of thoſe extenſive combinations of thought which conſtitute a chain of reaſoning. It would appear from this, and from the remark in page 39, that all the operations of the human mind are founded on ſenſation, habit, memory, and ſpeech.

† Phil. Tranſ. Vol. XII. p. 842.

The only objects of imitation, are geſtures and ſounds. The imitation of geſtures ſeems, at firſt ſight, leſs unaccountable than that of ſounds ; for it is performed by members which are objects of ſight, and would therefore ſeem more eaſily transferrable to the correſponding parts of another perſon ; whereas the organs of voice are ſo hidden and minute, that we can have no knowledge of what parts are put in motion in order to produce ſound. But upon farther reflection, there ſeems little or no difference in this reſpect ; for, independently of anatomy, we know nothing of muſcles but by their effects ; and there ſeems no reaſon why the ear being affected by a ſound, ſhould not excite a given motion in the muſcles of the larynx and fauces, as well as that a geſture, by having its image impreſſed on the retina, ſhould excite motions in the legs or arms. Even where imitation, or any other action, is the reſult of deliberate volition in rational beings, the motion is not performed from a knowledge of their having muſcles. They only *will* the effect, without knowing by what means it is performed; for though it may ſeem obvious that all the motions of an animal are effected by the ſhortening of the fleſhy fibres, this is a fact with which thoſe only are acquainted who have ſome knowledge of anatomy and phyſiology, and may be conſidered as a fundamental and firſt-rate diſcovery in the natural hiſtory of the living body *.

There

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* This diſcovery cannot be traced to any particular improver of phyſiology, but ſeems to have ariſen, like many other diſcoveries in ſcience and the arts, rather

from

A ſtate of conſtant tenſion neceſſary to the action of muſcular fibres.

There ſtill remains to be mentioned, that important property of living muſcular fibres, which conſiſts in a perpetual ſtate of tenſion taking place at all times, in a greater or leſs degree, independent of any temporary ſtimulus. When any muſcular fibre in a living animal body, whether in a fleſhy muſcle or a blood-veſſel, is divided by inciſion, there is an immediate retraction of the ſeparated parts; and that this is their natural ſtate, is farther proved by the ſpontaneous motion which takes place in conſequence of the relaxation of an antagoniſt muſcle, as when the mouth is drawn to one ſide, in conſequence of *hemiplegia*. A certain degree of this tenſion is

from the gradual evolution of knowledge than the efforts of any individual. It has at all times been obſerved, that exertions of ſtrength produce a ſwelling and motion in the fleſhy parts of the extremities, and the word denoting a muſcle in different languages, is taken from the reſemblance of the motions under the ſkin to thoſe of a little nimble animal, ſuch as a mouſe or a lizard. A muſcle is called in Greek *μυς*, in Latin *muſculus*, or *lacertus*, and that muſcle which is ſo viſible near the ham of a quadruped when walking, is, in the common language of ſome parts of the country, called the *mouſe*. It is not aſcertained, ſo far as I know, who firſt aſcribed the motions of animals to the contraction of fleſhy fibres. There is no mention made of this in the works of Hippocrates, but it is very clearly ſtated by Galen; ſo that the diſcovery ſeems to have been made in ſome intervening period. This property of muſcles is ſo well aſcertained in modern times, that wherever we ſee a muſcular ſubſtance, we infer ſynthetically that ſome correſponding function muſt belong to it; and we find an irrefragable argument for the circulation of the blood, only from conſidering the heart as a muſcular ſubſtance. This ſubject has not been well underſtood till modern times, otherwiſe the circulation would moſt probably have been diſcovered ſooner; and even ſince this diſcovery, we find ſome phyſiologiſts ſo little acquainted with the nature of muſcular power, that they have invented a fanciful theory of the motion of the blood, by a ſuppoſed fermentation taking place in the cavity of the heart. We are chiefly indebted to Dr. Gliſſon, who lived about the middle of the laſt century, for the firſt correct ideas of the irritability and contractility of muſcular fibres.

neceſſary for the performance of the natural motions of the muſcles, whether voluntary or involuntary, and the vigor with which the ſeveral actions are performed, depends on the fibres poſſeſſing a due degree of this conſtant tone. In order to maintain this tone, there muſt every where be a counteracting mechanical power, and we perceive accordingly that the great muſcles are kept on the ſtretch by the bones, the heart and veſſels by the maſs of fluids, and the inteſtines by the *ingeſta*, and their natural contents.

The exceſs or defect of this productive of diſeaſes,

When this tenſion is either exceſſive or defective, various irregular and morbid actions are produced. The vaſcular ſyſtem is more apt to be affected by various degrees of natural tone than any other part of the body, the reaſon of which may be, that this very relaxation produces a greater capacity of the vaſcular ſyſtem, and the relative quantity of the maſs of fluids being thereby diminiſhed, the reſiliency and energy of the veſſels are not ſupported even by their former degree of diſtenſion. An exceſs of it may ariſe either from the too great elaſticity of the veſſels themſelves, or from plethora. The firſt is indicated by a hard pulſe, and that correſponding ſtate of the fluids which occaſions in blood, when drawn from a vein and cold, a contraction of the craſſamentum, and a ſizy cruſt. Plethora is moſt apt to ariſe in conſtitutions naturally too lax, and which, therefore, do not bear the loſs of blood ſo well as the former.

A defect of tenſion in the veſſels is produced either by diſeaſe, by hæmorrhage, or by natural conſtitution. In diſeaſes, this want of tenſion is indicated by general debility and depreſſion of ſpirits, and by a weakneſs of the pulſe. And as irritibility and ſenſibility are very much affected by tenſion, a want of it in the veſſels chiefly conſtitutes what is called a nervous habit, ſuch as is moſt commonly met with in the female ſex ; and there is nothing more apt to induce ſuch a habit than hæmorrhage, which I have known to produce a long train of hyſterical ſymptoms in thoſe who had not formerly been ſubject to ſuch complaints.

There is a particular conſtitution incident to both ſexes, which is commonly connected with corpulency, and has been called by authors the *temperamentum frigidum*, *phlegmaticum*, and *ſpongioſum*, and, in common language, a groſs and flabby habit. In theſe there ſeems to be a deficiency of the natural elaſticity of the veſſels, and in certain diſeaſes, even of the inflammatory kind, ſuch as the eryſipelas, to which they are liable, tonic remedies, ſuch as the Peruvian bark, are found to be the cure, and in diſeaſes of the lungs, chalybeate remedies have been found effectual.

characteriſtic of conſtitutions,

There is, perhaps, no circumſtance in which one individual differs more from another, than this natural tenſion of the muſcular fibres ; and it would be more uſeful, as well as more conformable to nature, to found a diſcrimination of temperaments upon this, than upon the fanciful theory of humours ; for this difference of conſtitution not only gives occaſion to a variety in natural aſpect, but valuable inferences may be deduced from it in the pathology and treatment of diſeaſes.

ſubject to inequality,

Not only the general exceſs or defect of tenſion, but the inequality of it, may be conſidered as a cauſe of diſeaſe. It ſeems highly probable that thoſe local affections which depend on the congeſtion of fluids, are owing to the difference of tenſion in particular parts in relation to the whole ſyſtem. The whole arteries of the body may be conſidered as one veſſel, the capacity of which is equal to the ſum total of all the branches of the arterial ſyſtem, and as every part muſt be equally diſtended by the maſs of fluids, it follows that if the ſtrength of the veſſels of any one part ſhould not be ſufficient to ſupport an equilibrium, they muſt yield more or leſs to the elaſtic preſſure of the reſt of the ſyſtem.

and much influenced by ſympathy.

There is, however, a circumſtance of great importance in the animal œconomy, which muſt tend in ſome meaſure to counteract this inequality of tenſion. When the muſcular fibres of any particular part are under a ſtate of more or leſs tenſion than the reſt of the ſyſtem, this is communicated by ſympathy to every other part of the body. This is particularly obſervable in the blood veſſels and inteſtines; for a relaxation in any part of theſe will produce a like affection in every other part of the animal ſyſtem. With regard to the inteſtines, it may be mentioned, among many other proofs, that it is common for perſons in a ſtate of great weakneſs to be affected with ſyncope, and even inſtantaneous death, in the act of evacuating the bowels. It ſeems to be from a like cauſe that a temporary lowneſs is produced by an abſceſs being opened. This principle of the animal œconomy has been better illuſtrated by Dr. Cullen than any other phyſiologiſt; and he is of opinion, that great part of the effect of blood-letting in taking off the tenſion of the vaſcular ſyſtem, in caſes of inflammation, depends on the depletion of the veſſels of the part from whence the blood is taken, for the proportion of the quantity drawn to the whole maſs is very ſmall; and it may alſo be urged in favour of this opinion, that the more ſuddenly the evacuation is made, the more effectual is its operation in removing the inflammatory diſpoſition, inaſmuch as the local depletion will be greater, the leſs time is allowed for the balance of the ſyſtem to replace it.

WHAT

Muſcular motion conſidered mechanically.

WHAT has been hitherto ſaid of Muſcular Motion, has had relation to it as a property peculiar to animal matter and animal life. What I have farther to add on this ſubject, will relate to the muſcles merely as mechanical powers. As they conſtitute the ſtrength of animals, it may be proper to conſider the relation of their force to their bulk, and the relation of the bulk and ſtrength of the body to the denſity and coheſion of its own materials, and to the bulk, denſity, and coheſion of the external inanimate bodies with which it is converſant.

It has been demonſtrated by Galileo *, that in ſimilar unequal bodies of a cylindrical or priſmatic ſhape, ſuch as the limbs of animals nearly are, the ratio of their efforts to break by their own weight, is in the quadruplicate ratio of their lengths, but that the reſiſtance they make to the ſame force is only in the triplicate ratio of their lengths. It follows from this, that in order to endow the limbs of animals with the ſame relative force, it is not only neceſſary that the bones ſhould poſſeſs an encreaſed proportion of thickneſs, in order to give an adequate increaſe of what may be called the dead ſtrength, but a ſimilar increaſe of living ſtrength will be neceſſary, by a ſuitable addition of muſcular power, in order to keep pace with the increaſed ſize of the bones. Now we obſerve, in fact, that in the large-ſized animals, ſuch as the bull and the elephant, the thickneſs both of their bones and muſcles bears a greater proportion to the length of their limbs, than in the ſmaller animals, and they are therefore of a leſs elegant form. But Nature has not carried this ſo far, as to compenſate for the diſadvantage

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* Vid. Opere di Galileo. Diſcorſi e demonſtrazione mathematiche.

ariſing from the increaſe of ſize; for the greater animals have not the ſame proportional ſtrength, in relation to their bulk, that the ſmaller animals have. It has been computed * that a flea can draw from ſeventy to eighty times its own weight, whereas a horſe cannot with eaſe draw more than three times his own weight. This diſproportion between ſtrength and ſize is very obſervable in different individuals of the human ſpecies, when compared to each other; for tall men are not muſcular, even in the ſimple proportion of their ſtature. The difference in the ſhape and ſize of different men may be conſidered as an accidental variety, or *luſus naturæ*, owing, probably, to his artificial mode of life, and for which Nature has made no ſpecial proviſion.

The ſtrength and ſtature of the body properly adapted to external nature.

We are led, however, from a view of the ſame mechanical principles, to perceive the wiſdom of Nature in aſſigning certain general limits to the ſtature of the human body. Had man been made much larger, he would have been unwieldy, and ſubject to accidents in his motions, in conſequence of the *momentum* of the parts increaſing in a higher ratio than their power of reſiſtance. It may be anſwered, that the parts might have been made proportionally more hard and tenacious. But there are other circumſtances in the animal œconomy which would have been a bar to this; for had the bones been harder, they would not have been calculated for the common duration of life, the effect of which being to increaſe their hardneſs and dryneſs, they muſt be endowed originally with a certain degree of ſoftneſs and ſucculence. And with regard to muſcles, a degree of hardneſs, much greater than they naturally poſſeſs, would have been incompatible with their contractility.

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* Vid. Haller Elementa Phyſiologiæ. Cap. IX. Sect. II.

Another inconvenience of the greater ſtature of man would be, that he would require larger habitations, more food and clothing, while he would have leſs relative ſtrength to provide for theſe wants. On the other hand, had man been of a ſtature much leſs than what he enjoys by nature, he would not have poſſeſſed ſufficient power over external objects, to act up to thoſe ſuperior faculties of mind with which he is endowed. If nature had conferred on man only one half of his actual ſtature and ſtrength, with the ſame powers of reaſon, we may venture to affirm that he would not have carried his dominion over nature to the ſame extent. As he is now conſtituted, his force being commenſurate with external nature, he has been able, either by force or artifice, to aſſert his ſovereignty over the woods and fields, by maſtering the ſtrongeſt and fierceſt wild beaſts; he has been able to change the whole face of nature on the ſurface of the earth, by works of induſtry, and monuments of art; he has been able to fell trees, to build ſhips, and to circumnavigate the planet he inhabits. It is rather a triumph of his reaſon than of his corporeal ſtrength, to ſay, in the language of a modern poet *, that he can

> "Meaſure earth, weigh air, and ſtate the tides;"

or, according to the ſublime idea of an ancient philoſopher †, that he could turn the earth from its orbit, could he find footing on another earth, from whence to exert the powers of mechaniſm; but ſuch knowledge and ſuch conceptions could never have been attained but by a being of a certain degree of bodily ſtrength and ſtature.

From what has been ſaid, it may ſafely be inferred, that as the external bodies with which we are converſant poſſeſs given degrees

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* Pope. † Archimedes.

of coheſion, bulk, and denſity, which require correſponding powers to act upon them; ſo the human body, at its mean ſtature, is beſt adapted for producing thoſe changes upon matter, which are neceſſary for ſelf-preſervation, and the various accommodations of life. And an argument may be drawn from hence againſt the tenets of thoſe ſpeculative philoſophers, who hold that the ſize and ſtrength of man were much greater in remote antiquity than in modern times. It is evident, from what has been ſaid, that if the bulk of the human body were much greater than it is, it would be both uſeleſs and inconvenient, and would not preſerve that harmony with the reſt of nature, which is ſo agreeable to the analogy of her other works.

The muſcles conſidered as mechanical powers acting upon levers.

I ſhall conclude this Lecture with ſome remarks on the muſcles, conſidered as mechanical powers acting upon levers.

Their diſadvantageous action, 1. From the manner of their inſertion into the bones.

The firſt remark to be made upon this, is ſo obvious, that it has hardly eſcaped the notice of any modern phyſiologiſt, and ſeems at firſt ſight to militate againſt that wiſdom of nature which is ſo conſpicuous in other reſpects. What I mean is, the great waſte of mechanical power which is incurred by the manner in which the muſcles are inſerted into the bones. This diſadvantageous action of muſcles is chiefly owing to two circumſtances. One of theſe is their inſertion, in almoſt every inſtance in which they are connected with bones, into a part which is much nearer the fulcrum than the reſiſtance. Thus the two muſcles of the arm, called the *biceps* and *brachiæus internus*, in order to ſupport in the hand a weight of one pound with the fore arm at right angles to the *humerus*, muſt exert a power equal to ten pounds. The other circumſtance giving riſe to a waſte of power, is the great obliquity with which they are inſerted into the bones upon which they are intended to act, ſo that the greater part of the force is expended in preſſing one bone againſt another at the articulation, and only a ſmall portion of it in making the flexures and extenſions; ſo as to produce the deſired effect at the extremity.

This compenſated by preſerving the ſhape of the parts,

But theſe diſadvantages are compenſated by certain conveniences, and if nature has endowed the muſcles with ſufficient power for the purpoſes of life, after making allowance for the waſte of force, there can be no reaſon to find fault with her management. One of the principal advantages ariſing from this diſtribution of the muſcles, is the preſervation of the ſhape of the members; for unleſs the muſcles and tendons had been pretty nearly in the direction of the bones, they muſt have paſſed like bow-ſtrings from one bone to another, in making the flexures of the joints.

and in actions of percuſſion,

In eſtimating the waſte of force, in conſequence of the mechanical diſadvantages before mentioned, we are to diſtinguiſh between thoſe actions which conſiſt in preſſure, and thoſe which conſiſt in percuſſion; for as the *momentum* of the latter depends on velocity, it is evident that there is a great advantage from the inſertion of the tendon being near the centre of motion, as greater velocity, with leſs expence of contraction, will be thereby imparted to the extremity. The muſcles, for inſtance, which are attached to the *olecranon*, in performing thoſe actions with the hand which require rubbing, act with a diſadvantage, exactly in proportion to the inequality of the diſtance from their inſertion to the joint of the elbow, and that from the ſame joint to the hand. This is an act of preſſure. But in the caſe of percuſſion, as in the action of uſing a hammer, there is an evident advantage reſulting from the velocity communicated to the extremity ; for in order to have produced the ſame velocity, with the inſertion at a greater diſtance from the centre of motion, a greater range of contraction would have been neceſſary. The ſaving of contraction, therefore, may be reckoned another principal advantage in the attachment of muſcles near to the centre of motion. As this is a point which I think has not been attended to, in explaining the mechaniſm of the muſcles, I ſhall conclude with ſome remarks upon it.

by ſaving contraction.

2. Diſadvantage from the obliquity of muſcles to each other.

As the muſcles of voluntary motion are ſubject to fatigue, every circumſtance that can tend to diminiſh this, will be favourable to the purpoſes of nature. Fatigue depends upon the force, frequency, duration, and extent of the contraction of muſcular fibres. It is this laſt which is meant here to be illuſtrated. If any one will take the trouble of comparing the fatigue of the *biceps* muſcle, in bearing a weight in the hand, with the elbow joint bent to a right angle, with that of bearing the ſame weight for the ſame length of time, with the joint at an acute angle, he will be ſenſible how much the degree of fatigue depends on the extent of contraction, and by attending to the relative ſituation of muſcular fibres, it will appear that nature, in diſtributing the fibres of muſcles obliquely, has had it in view not only to increaſe their number, but to ſave contraction.

Oblique action univerſal in muſcles, in relation to each other.

In ſurveying the actions of all the various muſcles, it appears, not only from the co-operation of different muſcles, but from the poſition of the fibres in the ſame muſcle, that there is hardly an action to be met with that can be called direct. In ſome inſtances, two muſcles, or ſets of muſcles, are made to co-operate, ſo that the

the motion effected by them ſhall be in the diagonal of their direction. This is the caſe of the oblique muſcles of the abdomen in ſome of their actions, and the intercoſtal muſcles in all their actions. Sometimes, different portions of the ſame muſcle produce in like manner an intermediate and combined effect, as in the inſtance of the *cucullaris*, one part of which being attached to the *vertebræ* of the neck, and another to thoſe of the lower part of the back, their joint effect is to draw the *ſcapula* towards the ſpine. And in all the long muſcles, however ſimple their origin and inſertion may be, there is an internal obliquity of their fibres, in regard to each other, as deſcribed by the late Dr. Hunter; for theſe do not run from end to end, but there are parts of the tendon running into the belly of the muſcle, ſo as to divide it into penniform and rhomboidal portions. This diſtribution of the fibres takes off from their length; but as it takes place in thoſe caſes where the origin and inſertion are at a conſiderable diſtance, this can be afforded; and this, as well as the waſte of power, in conſequence of oblique action, is more than compenſated by the increaſed ſtrength, from the fibres being multiplied; for, in conſequence of this ſtructure, there is an extent of tendon afforded ſufficient for the inſertion of a greater quantity of fleſhy fibres.

and in the fibres of the ſame muſcle.

Compenſated, 1. by multiplying the number of fibres.

This illuſtrated in the ſtructure of fiſh.

This principle in the mechaniſm of muſcular action, is well illuſtrated by conſidering the motions of fiſh. The muſcles of moſt fiſh conſiſt of regular ſeries of oblique ſhort fibres, forming thoſe *ſtrata* which every one muſt have obſerved in their muſcular ſubſtance. Their motions are more ſimple and limited than thoſe of land animals, but much more vigorous; for a fiſh in the ſea has to make its way through a medium about a thouſand times more denſe than air, and with more rapidity. Nature, therefore, inſtead of giving them muſcles whoſe fibres would run ſtraight from one end of their body to the other, has multiplied their numbers, by diſtributing them into ſhort and oblique portions. If one was called upon to name inſtances of the greateſt muſcular efforts, it is in fiſh that theſe are to be found. I have ſeen the ſword of a ſword-fiſh ſticking in a plank, which it had penetrated from ſide to ſide; and when it is conſidered that the animal was then moving through ſo denſe a medium, and in the ſame direction with the ſhip, we muſt form a high conception of its muſcular power.

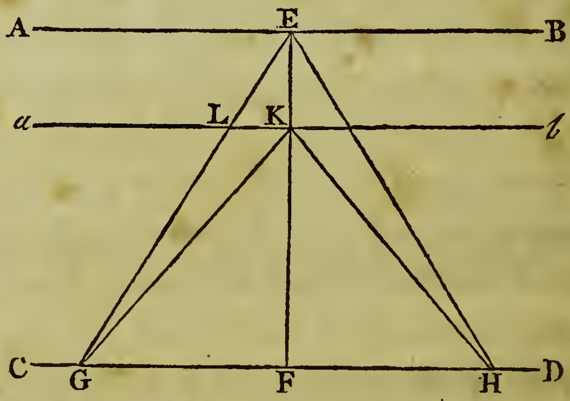
An advantage the reverſe of what has been ſtated, ariſes from the oblique direction of the intercoſtal muſcles, the fibres of which are thereby lengthened; for in parts ſo near each other as the ribs, there would have been a great inconvenience in their paſſing directly from one to another. Beſides, in conſequence of their oblique direction, the origin in the ſuperior rib is placed nearer to the centre of motion than the inſertion in the inferior rib, the effect of which is, that all the ribs are elevated, whereby the cavity of the thorax is enlarged, which is the view of nature.

2. By ſaving contraction.

But the advantage or rather compenſation of obliquity, which I mean particularly here to demonſtrate, is, that the ſame effect is produced with a leſs proportional decurtation of fibres, than if the ſame motion had been performed by a direct power. Borelli has eſtimated geometrically the loſs of power from oblique action, but ſeems to have overlooked this compenſation of it, which is not inconſiderable, when we reflect that there is thereby a ſaving of contraction, and conſequently of fatigue. This can be rendered an object of geometrical proof, and I here ſubjoin a demonſtration of it, which I made out, when engaged in the ſtudy of anatomy, eighteen years ago.

This demonſtrated by a theorem.

Let the line A B, in the annexed diagram, repreſent a moveable bone, and the line C D a fixed bone parallel to it. Let F E, perpendicular to theſe lines, repreſent a muſcle acting in its own direction, and the lines G E H E repreſent two muſcles acting obliquely, and producing, by a diagonal action, the ſame effect as the other, If the bone A B be brought to the ſituation *a b*, by the action of the muſcle F E, the muſcle will then be in the ſituation F K. If the bone is brought into the ſame ſituation by the action of the muſcles G E, H E, theſe muſcles will then be in the ſituation G K, H K.



The propoſition to be demonſtrated is, that the line G K bears a greater proportion to the line G E, than the line F K does to line F E ; for F K is to F E as G L is to G E. (Euc. Elem. B. vi. Prop. 2.) and the angle E L K, being leſs than a right angle, the angle G L K, which is adjacent to it, muſt be greater than a right angle; and the angle G K L, being in the ſame triangle with G L K, muſt be leſs than a right angle. The line G K, therefore, which ſubtends the greater angle, is greater than the line G L, ſubtending the leſſer, and therefore bears a greater proportion to G E. But the line G L is to G E, as F K is to F E; and therefore G K bears a greater proportion to G E, than F K does to F E; that is, the fibres of the muſcles acting obliquely, ſuffer a leſs proportional decurtation than thoſe of the muſcle acting directly.

It is farther obvious, that the more oblique the action becomes, the greater ſaving there will be of contraction; for in moving the line *a b* towards C D, the line F K diminiſhes in a ſwifter ratio than the line G K, and when the former has vaniſhed, the latter is in the ſituation G F.

Concluſion.

I have thus endeavoured to ſketch ſome of the moſt important particulars in the natural motions of living animals, a ſubject which affords one of the fineſt and moſt fertile fields for contemplating the wiſdom with which Nature adapts her means to her ends; and which has been juſtly conſidered as carrying the moſt irreſiſtible evidence of the exiſtence of an intelligent cauſe. The ſubject is ſo far from being exhauſted, that I am convinced there are circumſtances in the relative diſtribution and correſpondence of organs, depending on muſcular motion, ſo profound and exquiſite, as far to exceed the utmoſt reach of human thought to comprehend, or of human ingenuity to detect: and here, as in every other part of the frame of the univerſe, the moſt elevated conceptions which the moſt enraptur~~ous~~ed imagination can form of the beauty and magnificence of Nature, will fall far ſhort of the real ſublimity of her works.

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THE END.